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Introduction

Colorectal cancer was the most frequent cancer type in Germany for many years and is currently still the second most frequent type of tumor after breast cancer. About 70% of colorectal cancers are located in the colon and ~30% in the rectum (Robert Koch-Institut and Association of Population-based Cancer Registries in Germany, 2012). At the time of diagnosis, more than half of the patients are older than 70 years of age and 10% are younger than 55 years of age. When clinically diagnosed, more than 50% of colorectal cancers are in an advanced stage (Cancer Registry Baden-Württemberg, 2012).

In Germany, population-based colorectal cancer screening on the basis of fecal occult blood testing (FOBT) with colonoscopic follow-up of positive test results has been offered since 1977 to individuals from the age of 50 years. While FOBT screening continues to be offered, screening colonoscopy was introduced in 2002 from the age of 55. If the first screening colonoscopy was performed before the age of 65 years with a negative result, a second is offered 10 years later. Generally, there is no organized structure for inviting or reminding individuals to participate in colorectal cancer screening. Thus, it is an opportunistic screening program, that is, the information on and utilization of the offer fully depends on the initiative of eligible individuals themselves or their physicians. Since 2003 an overall attendance of about 22% of the eligible population made use of this offer (Maar, 2012).

Various European research projects have shown that the participation in screening programs is influenced by the socioeconomic status (SES) of eligible individuals (Wardle *et al.*, 2004; Von Wagner *et al.*, 2009; Frederiksen *et al.*, 2010; Pornet *et al.*, 2010). For Germany, however, the information on determinants of attendance at screening colonoscopy is limited as the required data were not collected routinely. Even then, such data would not provide a full insight into utilization of colonoscopy, given that colonoscopies are also performed for reasons other than screening. We used a large, population-based cohort study (EPIC–Heidelberg, one of the two German subcohorts of the large European Prospective

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Investigation into Cancer and Nutrition) to estimate the utilization of colonoscopy and its association with SES characteristics in Germany (Riboli and Kaaks, 1997; Boeing *et al.*, 1999a, 1999b). The EPIC study was designed to evaluate the associations between diet, nutritional status, lifestyle, and environmental factors and the incidence of cancer and other chronic diseases.

Materials and methods

Between 1994 and 1998, EPIC–Heidelberg recruited 13 612 women (aged 35–60 years) and 11 928 men (aged 40–65 years). All participants of EPIC–Heidelberg provided written informed consent and the study was approved by the Ethics Committee of the Heidelberg Medical Faculty.

At baseline, the study participants completed a self-administered questionnaire and an interview to provide information on physical activity, alcohol and tobacco consumption, medical history, and previous and present medical treatments. Furthermore, anthropometric measurements and blood samples were taken. In the following years, the participants were asked to complete follow-up questionnaires at regular 3-year intervals to provide continuous information on major chronic disease risk factors and health status. In the context of the first follow-up (1999–2001), the study participants were asked whether a FOBT had ever been performed. Because of the fact that colonoscopy was introduced as a screening method in 2002, a question on utilization of colonoscopy was included from the second follow-up (2001–2003) onwards. Initially, it was asked whether a colonoscopy had ever been performed and, if yes, the participant was asked to report the date of the examination. In the third (2004–2006) and fourth follow-up (2007–2009), it was asked whether a colonoscopy had been performed since the last follow-up and, if yes, the date of colonoscopy was asked for. In the present data analysis, only participants who completed the question on colonoscopy examination in all three rounds of follow-up (second, third, and fourth follow-ups) were included ($n = 15\,014$).

Statistical analysis

To generate the variable *never/ever colonoscopy* the relevant questions of the second, third, and fourth follow-ups were taken into account. This enables a descriptive analysis of the cumulative utilization of colonoscopy.

The SES variables documented in the baseline questionnaire were used to categorize the participants as follows: (a) level of formal education [none, *Hauptschule* (secondary school I), *Realschule* (secondary school II), or *Gymnasium* (high school)], (b) vocational training, a specific education that trains a skill or trade to be pursued as a career (none, industrial training, vocational/technical school, or technical college/university), (c) employment status (never employed, currently not employed, or employed), (d) marital status (single, widowed, separated, or married), (e) household size (one, two, three, or four or more persons), and (f) spatial setting (rural, semiurban, or urban). Spatial settings were evaluated on the basis of the ZIP code stated at baseline. This code was linked with data from the Federal Institute for Research on Building, Urban Affairs and Spatial Development, categorizing the place of living into rural, semiurban, and urban areas.

On the basis of the International Standard Classification of Education (ISCED), the education and vocational training variables were combined into a new variable describing SES. According to the guidelines (Schroedter, 2006), this variable differentiates between three SES levels: low, medium, and high.

To describe the cumulative utilization of colonoscopy, the reported colonoscopies were summed up over time. If in any of the three follow-up questionnaires the participant stated that they had had a colonoscopy, he or she was assigned to the 'ever' group, otherwise they were assigned to the 'never' group.

Logistic regression models were used to compute odds ratios (ORs) for having had a colonoscopy, and corresponding 95% confidence intervals (CIs), in relation to age, sex, and socioeconomic determinants. The six SES variables were each included in an age-adjusted (age at second follow-up, continuous) model. The statistical analyses were carried out using SAS 9.3 (SAS Institute, Cary, North Carolina, USA).

Results

Socioeconomic and demographic characteristics

Table 1 shows the baseline SES characteristics of the EPIC–Heidelberg cohort. About 40.5% of all participants included in this analysis were born between 1941 and 1951. In all, 38.6% of the participants had graduated from high school, men reaching this level more frequently than the women in this cohort (43.4 and 34.9%, respectively).

The vocational training differed by sex, women stating they had not had any vocational training almost four times more often than men (9.4 and 2.5%, respectively). Men most frequently reported a university degree (41.1%), whereas women often reported vocational school graduation (36.2%). The distribution across the ISCED classification shows that 34.2% of the cohort is assigned to the medium SES. At baseline, only 0.5% of the included participants had never been employed; of these 75 individuals, 70 were women. Compared with 83.3% of the men, only 68.2% of the women declared that they were employed at baseline.

At recruitment, 77.9% of the participants were married (men: 83.9%, women: 73.4%) and 2.9% stated they were widowed. In all, 39% of the participants reported living in a two-person household (men: 40.7%, women: 37.7%), and only 11.8% lived alone (men: 8.6%, women: 14.2%).

Table 1 Socioeconomic status characteristics of the participants at baseline of the EPIC–Heidelberg cohort included in this analysis

Socioeconomic and demographic characteristics	Male cohort population [*N* (%)]	Female cohort population [*N* (%)]	Total cohort population [*N* (%)]
Birth year [age (median) at fourth follow-up]	6502 (100)	8512 (100)	15 014 (100)
1930–1940 (71.0)	2204 (33.9)	2081 (24.5)	4285 (28.5)
1941–1951 (61.6)	2932 (45.1)	3153 (37.0)	6085 (40.5)
1952–1963 (51.7)	1366 (21.0)	3278 (38.5)	4644 (30.9)
Education	6501 (100)	8510 (100)	15 011 (100)
None	26 (0.4)	33 (0.4)	59 (0.4)
Secondary school I (Hauptschule)	2598 (40.0)	3066 (36.0)	5664 (37.7)
Secondary school II (Realschule)	1057 (16.3)	2444 (28.7)	3501 (23.3)
High school (Gymnasium)	2820 (43.4)	2967 (34.9)	5787 (38.6)
Vocational training	6501 (100)	8509 (100)	15 010 (100)
None	159 (2.5)	802 (9.4)	961 (6.4)
Industrial training	2111 (32.5)	2350 (27.6)	4461 (29.7)
Vocational school	1559 (24.0)	3083 (36.2)	4642 (30.9)
Technical college/ university degree	2672 (41.1)	2274 (26.7)	4946 (33.0)
ISCED classification	6501 (100)	8510 (100)	15 011 (100)
Low	2094 (32.2)	2844 (33.4)	4938 (32.9)
Medium	1735 (26.7)	3392 (39.9)	5127 (34.2)
High	2672 (41.1)	2274 (26.7)	4946 (34.0)
Employment status	6501 (100)	8512 (100)	15 013 (100)
Never employed	5 (0.1)	70 (0.8)	75 (0.5)
Currently not employed	1079 (16.6)	2635 (31.0)	3714 (24.7)
Employed	5417 (83.3)	5807 (68.2)	11 224 (74.8)
Marital status	6500 (100)	8510 (100)	15 010 (100)
Single	528 (8.1)	976 (11.5)	1504 (10.0)
Widowed	68 (1.1)	363 (4.3)	431 (2.9)
Separated	449 (6.9)	929 (10.9)	1378 (9.2)
Married	5455 (83.9)	6242 (73.4)	11 697 (77.9)
Household size	6499 (100)	8510 (100)	15 009 (100)
One	560 (8.6)	1209 (14.2)	1769 (11.8)
Two	2648 (40.7)	3209 (37.7)	5857 (39.0)
Three	1374 (21.1)	1669 (19.6)	3043 (20.3)
≥ Four	1917 (29.5)	2423 (28.5)	4340 (28.9)
Spatial observation	6489 (100)	8494 (100)	14 983 (100)
Rural	41 (0.6)	49 (0.6)	90 (0.6)
Semiurban	630 (9.7)	810 (9.5)	1440 (9.6)
Urban	5818 (89.7)	7635 (89.9)	13 453 (89.8)

EPIC, European Prospective Investigation into Cancer and Nutrition; ISCED, International Standard Classification of Education.

The spatial setting did not differ between men and women, with the majority of both living in an urban area (90%).

Number of colonoscopies

Of the 15 014 participants, 7142 reported to never having had a colonoscopy and 7872 individuals reported having had at least one colonoscopy (Table 2).

At the end of the fourth follow-up, 11 109 study participants were 55 years or older and were thus entitled to undergo screening colonoscopy. Of these, 60% actually reported having had a colonoscopy. Of the 5706 participants who were older than 65, 66% stated ever having had a colonoscopy performed (data not shown).

Figure 1 shows the distribution of first-time colonoscopy according to age and sex. Because of missing data on colonoscopy, 474 women and 361 men could not be included in this analysis. For both sexes, the first colonoscopies were most frequently performed in the age groups 55–59 and 60–64 and decreased strongly after the age of 69.

Although after the second follow-up less than 25% of the study population reported ever having had a colonoscopy, the proportion was just above 50% by the end of the fourth follow-up (data not shown). When examining the ever-use of colonoscopy by 1-year age groups at the time of the fourth follow-up, it becomes apparent that the proportion of ever-users is above 50% among the 58-year-old participants and peaks at age 67 (68.8%) (Fig. 2).

Colonoscopy and socioeconomic and demographic factors

In Table 3, the cohort was divided into two subgroups: those who had never had a colonoscopy and those who had had one or more colonoscopies (referred to as 'ever'). Participants born between 1941 and 1951 had had a colonoscopy examination most frequently (45.4%); this result was similar for both sexes. Of the participants born one decade earlier, 35.7% had had a colonoscopy; of the study participants born between 1952 and 1963, 18.9% reported a colonoscopy.

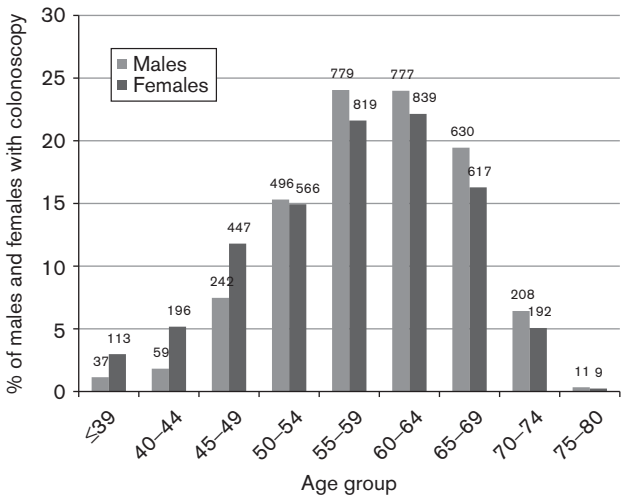
Of the female participants who had had a colonoscopy, 40.4% had completed secondary school I, whereas 39.3% of women who never had a colonoscopy had graduated from high school. A closer examination of marital status shows that 7.7% of the participants with a colonoscopy were single at baseline compared with 12.6% of those without a colonoscopy, which is similar in the sex-specific analysis (Table 3). The distribution of household size is comparable between the two subgroups. For the four remaining variables (vocational training, ISCED classification, employment status, and spatial observations), the distribution does not differ considerably between the participants with and without a colonoscopy.

Table 2 Number of colonoscopies in male and female EPIC–Heidelberg participants

	No colonoscopy [*N* (%)]	One colonoscopy [N (%)]	Two colonoscopies [*N* (%)]	Three colonoscopies [*N* (%)]
All study participants ($n = 15\,014$)	7142 (47.6)	4385 (29.2)	2560 (17.1)	927 (6.2)
Males ($n = 6502$)	2902 (44.6)	1916 (29.5)	1223 (18.8)	461 (7.1)
Females ($n = 8510$)	4240 (49.8)	2469 (29.0)	1337 (15.7)	466 (5.5)

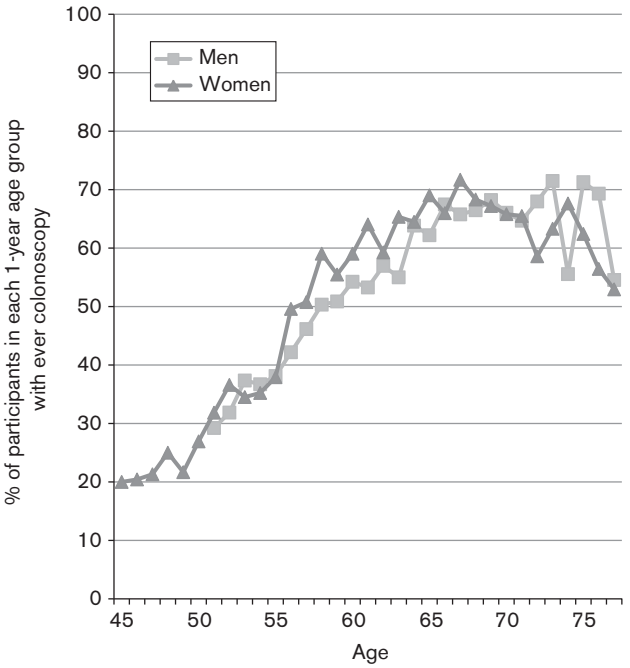
EPIC, European Prospective Investigation into Cancer and Nutrition.

Fig. 1



Distribution of individuals who ever had colonoscopy according to sex and age at first colonoscopy ($n = 7037$).

Fig. 2



Participants (in % of each 1-year age group) with ever colonoscopy at age of the fourth follow-up.

Comparison of participants born between the years 1941 and 1951 with those born a decade earlier shows that colonoscopies were more frequent for the younger participants (Table 3). This was statistically significant for the total cohort population (OR: 1.36, 95% CI: 1.19–1.56) as well as for the women (OR: 1.48, 95% CI: 1.23–1.79), and had borderline significance for the men (OR: 1.21, 95% CI: 0.99–1.46). Participants born yet another decade later had (nonsignificant) fewer colonoscopies than the oldest category.

The results for education and vocational training were inconsistent: for women, we found an inverse relationship between education and colonoscopy (P for trend = 0.013). This finding was significant when comparing individuals with high school diploma with those with secondary school I as the highest education (OR: 0.82, 95% CI: 0.69–0.97). For men and the total cohort population (men and women combined), this association was not observed. Here, the participants with no education had significantly increased ORs (total OR: 2.43, 95% CI: 1.29–4.57; men: OR: 3.90, 95% CI: 1.28–11.87). However, this group of participants is very small. The association between colonoscopy and vocational training was direct and consistent for the entire study population (P for trend < 0.0001), as well as for men (P for trend = 0.02) and women (P for trend = 0.0008) separately. Individuals in the two highest categories of the vocational training variable had had a colonoscopy more frequently than those with industrial training. This was significant for men with technical college or university degree (OR: 1.24, 95% CI: 1.01–1.52) as well as in the entire cohort population for those who had vocational school (OR: 1.10, 95% CI: 1.00–1.20) and technical college or university degree (OR: 1.24, 95% CI: 1.08–1.43) as the highest attained level of education. For women, these results had borderline significance (vocational school OR: 1.10, 95% CI: 0.98–1.24, technical college or university degree OR: 1.20, 95% CI: 0.99–1.44).

The ISCED classification variable generates SES levels by combining the education and vocational training variables. On examining the total cohort population, there is a significant positive association between colonoscopy and increasing SES levels (P for trend < 0.003). The participants with medium as well as the highest SES level had had colonoscopy examinations more frequently than participants at the lowest SES level. This significant association between SES level and colonoscopy exists for men (P for trend = 0.0005; high SES level OR: 1.24, 95% CI: 1.10–1.40), but not for women.

A negative association between colonoscopy and unemployment at baseline was significant for the total cohort (P for trend = 0.028) and among the women (P for trend = 0.036). Also, participants who documented never having been employed had a significantly lower utilization of colonoscopy than those who reported having been employed at the fourth follow-up (OR: 0.56, 95% CI: 0.35–0.91). However, both these associations are based on a very small number of individuals.

Utilization of colonoscopy was influenced by household size (P for trend = 0.037), indicating an inverse

Table 3 Association between socioeconomic and demographic characteristics of the study population and colonoscopy, divided into individuals who have ever or never had a colonoscopy

	Male cohort population			Female cohort population			Total cohort population		
Socioeconomic and demographic characteristics	Ever [*N* (column %)]	Never [*N* (column %)]	OR (95% CI)[a]	Ever [*N* (column %)]	Never [*N* (column %)]	OR (95% CI)[a]	Ever [*N* (column %)]	Never [*N* (column %)]	OR (95% CI)[a]
Birth year [age (median) at fourth follow-up]	3600	2902	*P* for trend = 0.62[a]	4272	4240	*P* for trend = 0.13[a]	7872	7142	*P* for trend = 0.24[a]
1930–1940 (71.0)	1463 (40.6)	741 (25.5)	1	1348 (31.6)	733 (17.3)	1	2811 (35.7)	1474 (20.6)	1
1941–1951 (61.6)	1644 (45.7)	1288 (44.4)	1.21 (0.99–1.49)	1929 (45.2)	1224 (28.9)	1.48 (1.23–1.79)	3573 (45.4)	2512 (35.2)	1.36 (1.19–1.56)
1952–1963 (51.7)	493 (13.7)	873 (30.1)	0.94 (0.67–1.32)	995 (23.3)	2283 (53.8)	0.81 (0.59–1.12)	1488 (18.9)	3156 (44.2)	0.88 (0.70–1.11)
Education	3600	2901	*P* for trend = 0.89[a]	4272	4238	*P* for trend = 0.013[a]	7872	7139	*P* for trend = 0.11[a]
Secondary school I	1445 (40.1)	1153 (39.7)	1	1726 (40.4)	1340 (31.6)	1	3171 (40.3)	2493 (34.9)	1
Secondary school II	586 (16.3)	471 (16.2)	1.13 (0.97–1.32)	1218 (28.5)	1226 (28.9)	0.94 (0.83–1.06)	1804 (22.9)	1697 (23.8)	1.03 (0.94–1.13)
High school	1549 (43.0)	1271 (43.8)	1.02 (0.83–1.24)	1303 (30.5)	1664 (39.3)	0.82 (0.69–0.97)	2852 (36.2)	2935 (41.1)	0.90 (0.79–1.02)
None	20 (0.6)	6 (0.2)	3.90 (1.28–11.87)	25 (0.6)	8 (0.2)	2.21 (0.96–5.09)	45 (0.6)	14 (0.2)	2.43 (1.29–4.57)
Vocational training	3600	2901	*P* for trend = 0.02[a]	4272	4237	*P* for trend = 0.0008[a]	7872	7138	*P* for trend < 0.0001[a]
Industrial training	1129 (31.4)	982 (33.9)	1	1137 (26.6)	1213 (28.6)	1	2266 (28.8)	2195 (30.8)	1
Vocational school	883 (24.5)	676 (23.3)	1.05 (0.91–1.21)	1649 (38.6)	1434 (33.8)	1.10 (0.98–1.24)	2532 (32.2)	2110 (29.6)	1.10 (1.00–1.20)
Technical college/university degree	1515 (42.1)	1157 (39.9)	1.24 (1.01–1.52)	1054 (24.7)	1220 (28.8)	1.20 (0.99–1.44)	2569 (32.6)	2377 (33.3)	1.24 (1.08–1.43)
None	73 (2.0)	86 (3.0)	0.84 (0.59–1.18)	432 (10.1)	370 (8.7)	0.85 (0.72–1.02)	505 (6.4)	456 (6.4)	0.89 (0.76–1.03)
ISCED classification[b]	3600	2901	*P* for trend = 0.0005[a]	4272	4238	*P* for trend = 0.37[a]	7872	7139	*P* for trend = 0.003[a]
Low	1123 (31.2)	971 (33.5)	1	1460 (34.2)	1384 (32.7)	1	2583 (32.8)	2355 (33.0)	1
Medium	962 (26.7)	773 (26.7)	1.06 (0.93–1.21)	1758 (41.2)	1634 (38.6)	1.08 (0.97–1.20)	2720 (34.6)	2407 (33.7)	1.08 (1.00–1.18)
High	1515 (42.1)	1157 (39.9)	1.24 (1.10–1.40)	1054 (24.7)	1220 (28.8)	1.05 (0.93–1.18)	2569 (32.6)	2377 (33.3)	1.14 (1.04–1.24)
Employment status	3600	2901	*P* for trend = 0.28[a]	4272	4240	*P* for trend = 0.036[a]	7872	7141	*P* for trend = 0.028[a]
Employed	2914 (80.9)	2503 (86.3)	1	2794 (65.4)	3013 (71.1)	1	5708 (72.5)	5516 (77.2)	1
Currently not employed	686 (19.1)	393 (13.6)	0.95 (0.81–1.11)	1445 (33.8)	1190 (28.1)	0.91 (0.81–1.01)	2131 (27.1)	1583 (22.2)	0.93 (0.85–1.01)
Never employed	0 (0)	5 (0.9)	–	33 (0.8)	37 (0.9)	0.66 (0.40–1.10)	33 (0.4)	42 (0.6)	0.56 (0.35–0.91)
Marital status	3598	2902	*P* for trend = 0.36[a]	4272	4238	*P* for trend = 0.23[a]	7870	7140	*P* for trend = 0.054[a]
Married	3108 (86.4)	2347 (80.9)	1	3183 (74.5)	3059 (72.2)	1	6291 (79.9)	5406 (75.7)	1
Divorced	227 (6.3)	222 (7.7)	1.11 (0.65–1.89)	491 (11.5)	438 (10.3)	1.11 (0.85–1.44)	718 (9.1)	660 (9.2)	1.06 (0.84–1.34)
Widowed	39 (1.1)	29 (1.0)	1.27 (0.76–2.11)	220 (5.2)	143 (3.4)	1.15 (0.90–1.46)	259 (3.3)	172 (2.4)	1.13 (0.91–1.40)
Single	224 (6.2)	304 (10.5)	0.93 (0.55–1.57)	378 (8.9)	598 (14.1)	0.88 (0.67–1.15)	602 (7.7)	902 (12.6)	0.84 (0.67–1.06)
Household size	3598	2901	*P* for trend = 0.32	4271	4239	*P* for trend = 0.15	7869	7140	*P* for trend = 0.037
One	268 (7.5)	292 (10.1)	1	633 (14.8)	576 (13.6)	1	901 (11.5)	868 (12.2)	1
Two	1625 (45.2)	1023 (35.3)	1.13 (0.89–1.43)	1846 (43.2)	1363 (32.2)	0.98 (0.83–1.17)	3471 (44.1)	2386 (33.4)	1.03 (0.90–1.19)
Three	746 (20.7)	628 (21.7)	0.99 (0.77–1.28)	823 (19.3)	846 (20.0)	0.92 (0.76–1.12)	1569 (19.9)	1474 (20.6)	0.94 (0.80–1.09)
≥Four	959 (26.7)	958 (33.0)	1.03 (0.79–1.33)	969 (22.7)	1454 (34.3)	0.90 (0.73–1.10)	1928 (24.5)	2412 (33.8)	0.93 (0.79–1.08)
Spatial observation	3596	2893	*P* for trend = 0.15	4264	4230	*P* for trend = 0.67	7860	7123	*P* for trend = 0.149
Urban	3246 (90.3)	2572 (88.9)	1	3849 (90.3)	3786 (89.5)	1	7095 (90.3)	6358 (89.3)	1
Semiurban	334 (9.3)	296 (10.2)	0.92 (0.77–1.09)	394 (9.2)	416 (9.8)	0.99 (0.85–1.16)	728 (9.3)	712 (10.0)	0.96 (0.86–1.08)
Rural	16 (0.5)	25 (0.9)	0.53 (0.28–1.02)	21 (0.5)	28 (0.7)	0.80 (0.44–1.47)	37 (0.5)	53 (0.7)	0.65 (0.42–1.01)

CI, confidence interval; ISCED, International Standard Classification of Education; OR, odds ratio.

[a]Adjusted for age at the second follow-up.

[b]When calculating OR and 95% CI for the variable ISCED classification, the variables education and vocational training were excluded from the statistical model.

association. However, none of the variable categories showed statistical significance.

In our analyses, we neither found an association between colonoscopy and marital status nor between colonoscopy and inhabiting rural/urban areas.

Discussion

We were interested in the uptake of colonoscopy screening in this cohort, the number of colonoscopies/individual reported, and whether SES variables had an impact on the uptake of colonoscopy examination. The results showed that ~52% of the EPIC–Heidelberg population reported to ever having had a colonoscopy by the end of the fourth follow-up. Of these, 32.5% documented two and 11.8% documented three colonoscopies. Colonoscopy was associated with some socioeconomic and demographic characteristics: a positive association with vocational training level as well as overall SES level (ISCED classification). A negative association was found for household size and employment status, those who had never been employed having the lowest uptake of colonoscopy.

International comparisons

It is difficult to compare our results with international data as colonoscopy is not included in colorectal cancer screening programs in most countries and generally the use of colonoscopy differs considerably between countries. The results of a survey conducted by the German Robert Koch Institute indicated that 86.4% of the German population older than 55 years of age is aware of the colorectal cancer screening possibility (Robert Koch-Institute, 2012). However, the awareness of the screening option does not necessarily translate into higher uptake rates. Since 2003, ~22% of those eligible to participate in the screening program actually took part. This percentage does not consider individuals who had had a colonoscopy for other reasons. It is estimated that between 40 and 50% of the population in the relevant age group has had a colonoscopy (Maar, 2012). Our results are comparable with this estimation: by the end of the fourth follow-up, 52% of all participants of the EPIC–Heidelberg cohort had had a colonoscopy. A review (Stock *et al.*, 2010) came to the conclusion that 56% of individuals aged 50 years and older had had a colonoscopy in the USA. We found a similar frequency of use of colonoscopy (57.8%) for individuals aged 56–66 at the fourth follow-up. However, only 31.2% of the participants between age 44 and 55 years of age stated they had had a colonoscopy. The difference between the USA and Germany may reflect the fact that the colorectal cancer screening program in the USA advises regular screening from the age of 50 years whereas, in Germany, screening colonoscopy is offered from the age of 55 years. A further publication (Scheffer *et al.*, 2006) reported that the prevalence of colonoscopy increased strongly with increasing age; our result shows that participants born between 1941 and 1951 have the highest likelihood of having had a colonoscopy. Previous German data collected in 2004 as part of the Health Care Access Panels survey showed that only 36% of the questioned individuals had had at least one colonoscopy in the past. The fact that screening colonoscopy had just commenced may explain the pronounced lower colonoscopy rate in the Health Care Access Panels survey compared with our results (52% colonoscopy). Furthermore, the Health Care Access Panels survey is a representative census, whereas in EPIC–Heidelberg it may be biased because of self-selection, resulting in higher screening participation (Sieverding *et al.*, 2010).

Socioeconomic and demographic factors

Data from the USA and Europe have shown that various SES factors influence the screening participation rate; in particular, older age, male sex, higher education, marriage, and employment have an impact (Scheffer *et al.*, 2006; Beydoun and Beydoun, 2008; Frederiksen *et al.*, 2010; Holden *et al.*, 2010; Pornet *et al.*, 2010; Von Wagner *et al.*, 2011). A German investigation observed a positive correlation between colorectal screening and income as well as with an urban place of residence (Association of Statutory Health Insurance Physicians, 2012).

Educational and vocational training

Frederiksen *et al.* (2010) reported higher colonoscopy use among individuals with better education or vocational training, whereas our results for education and vocational training were inconsistent. Although the relationship between colonoscopy and education tended to be inverse in our study, the association with vocational training was positive. Scheffer *et al.* (2006) reported that the significant positive association between colonoscopy and education was especially pronounced in women. Mielck and Brenner (1991) found this association only for employed women. In our data, this association was only significant for the total cohort and for the male population. Sieverding *et al.* (2010) did not find a clear association or trend between colonoscopy and education in both sexes. Unfortunately, it is not possible to compare our results in terms of the SES level defined by the ISCED classification as this has not been used in previous publications.

Employment status

As reviewed by Scheffer *et al.* (2006), the reported association between employment status and participation in German cancer screening programs is inconsistent, some studies showing a higher uptake among the unemployed and others showing the contrary, and yet others indicating no association at all. In agreement with Frederiksen *et al.* (2010), our analyses show that employed participants had a higher likelihood of having had a colonoscopy than currently not or never employed participants.

Marital status

The association between participation in cancer screening programs and marital status has not been evaluated in many studies. Although the marital status did not influence colonoscopy use among men and women in one study (Sieverding *et al.*, 2010), married individuals were more likely to report having undergone colorectal cancer screening in another (Seeff *et al.*, 2004). We found that single participants had a lower likelihood of having had a colonoscopy than married participants. Nowadays, household size may be more meaningful than the marital status. Mielck and Brenner (1991) as well as Frederiksen *et al.* (2010) observed that men and women living alone participated in screening programs less frequently, and Mielck and Brenner reported this as being most pronounced in unemployed women living on their own. In an investigation by Sieverding *et al.* (2010), household size was associated inversely with colonoscopy use in men, but not in women. Our analyses, however, did not show a significant association between household size and colonoscopy usage, and only the trend test for the total cohort was significant.

Urbanization

On behalf of the Association of Statutory Health Insurance Physicians (2012) (Kassenärztliche Vereinigung Bayerns), a study was carried out that evaluated the impact of rural or urban area of habitation on the usage of colonoscopy. This study led to the conclusion that the usage of screening colonoscopy was higher in urban areas. In our analysis, we did not find a significant association between colonoscopy and living in rural/urban areas, which, however, may be because we included all individuals who stated ever having had a colonoscopy and not only screening colonoscopy. Furthermore, the number of participants in our study living in a rural area is very small, limiting the possible statistical association. For further insight, research with larger numbers is necessary.

Limitations

This large prospective population study offers a solid base for epidemiological research. However, it has its limitations. First, our data cannot discriminate between individuals who had had a colonoscopy because of symptoms and individuals who had undergone a preventive colonoscopy. Second, we rely on self-reported colonoscopy. However, validation studies have shown that self-reported data on colonoscopy are very dependable (Baier *et al.*, 2000; Hall *et al.*, 2004; Hoffmeister *et al.*, 2007). Third, as only 38.5% of individuals originally invited (random population sample) had agreed to participate in the EPIC study, the studied cohort is a self-selected subgroup of the underlying population (Boeing *et al.*, 1999a, 1999b). As previous investigations have shown that the educational level of the EPIC–Heidelberg population is higher than that of the reference population, selection bias can be assumed. However, this selective participation does not prevent etiological conclusions as associations are derived internally as the relative risk (Boeing *et al.*, 1999a, 1999b). In the analyses presented here, only individuals who completed all three questions on colonoscopy utilization ($n = 15\,014$) were included. Comparing this subgroup with those not included in the analyses showed that a higher percentage of the excluded population is older, has a lower SES (ISCED classification), and stated more frequently that they were currently not employed. On the one hand, we would expect an older population to report more colonoscopies; thus, it is likely that our results underestimate the actual colonoscopy rate. On the other, individuals with a lower SES or unemployed individuals may consider colonoscopy less frequently.

A further limitation is related to the comparability of educational factors between countries because of different school and vocational training systems. We evaluated SES by using the variable education and vocational training separately as well as in a combined variable (ISCED classification). None of these three variables is optimal, but as income was not assessed, these variables seem to be adequate surrogates.

Conclusion

Our results show that by the end of the fourth follow-up, more than half of all participants of the EPIC–Heidelberg cohort had had a colonoscopy. SES factors influence the usage of colonoscopy, education and employment status having the greatest impact. To our knowledge, this is the first publication that shows cumulative number of colonoscopies in a prospective study cohort. In terms of the frequency of ever having a colonoscopy with advancing age, it was found that colonoscopy usage increases steeply within the subgroup of participants older than 55 years of age and decreases again after the age of 75 years. A bill passed in 2013 scheduled the introduction of organized colorectal cancer screening, including a written invitation system, by 2017 in Germany. It will be an important research question as to whether the written invitation system will overcome the problem of sociodemographic-related differential awareness of and attendance at colonoscopy as observed in this analysis. However, the high proportion of individuals with colonoscopy entering into the target age range suggests that previous attendance and potential diagnostic findings should be taken into account when scheduling the invitation, to establish an efficient screening program.

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Conflicts of interest

There are no conflicts of interest.

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